A Demonstration of RASSAR: Room Accessibility and Safety Scanning in Augmented Reality

Xia Su
Kaiming Cheng
Han Zhang
Jaewook Lee
Allen School of Computer Science,
University of Washington, Seattle
USA

Wyatt Olson
School of Art + Art History + Design,
University of Washington, Seattle
USA

Jon E. Froehlich
Allen School of Computer Science,
University of Washington, Seattle
USA

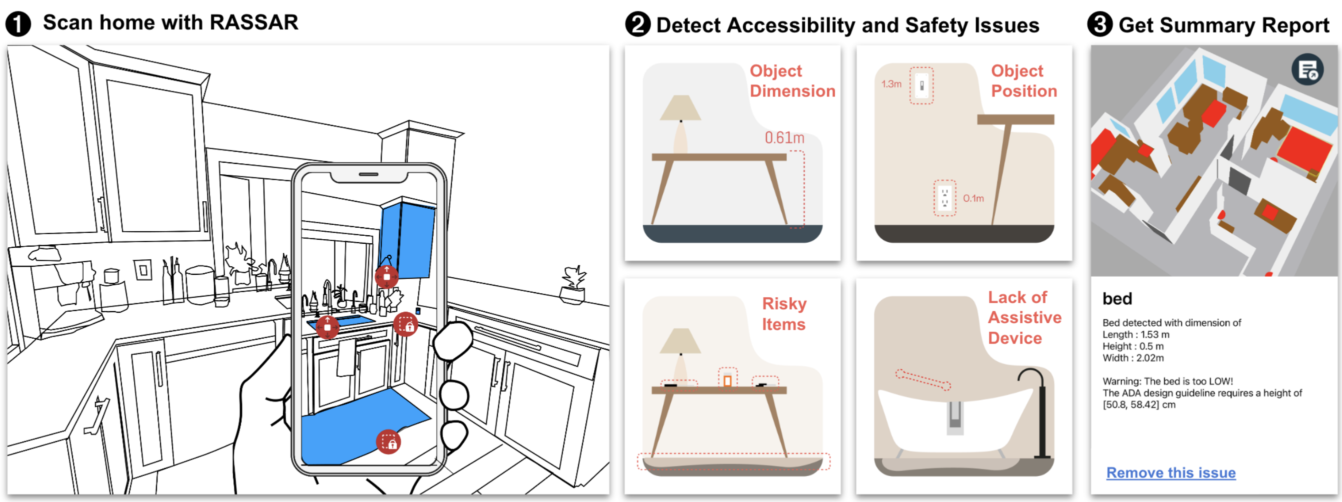

Figure 1: RASSAR is a mobile AR application for semi-automatically *identifying*, *localizing*, and *visualizing* accessibility and safety issues in indoor spaces. With RASSAR, a user (1): scans a space using their phone to detect (2) four classes of potential accessibility / safety issues in real-time and (3) also receives a post-scan summary with a 3D reconstruction and detected issues.

ABSTRACT

In this demo paper, we introduce *RASSAR*, a mobile AR application for semi-automatically *identifying*, *localizing*, and *visualizing* indoor accessibility and safety issues using LiDAR and real-time computer vision. Our prototype supports four classes of detection problems: inaccessible object dimensions (*e.g.,* table height), inaccessible object positions (*e.g.,* a light switch out of reach), the presence of unsafe items (*e.g.,* scissors), and the lack of proper assistive devices (*e.g.,* grab bars). RASSAR's design was informed by a formative interview study with 18 participants from five key stakeholder groups, including wheelchair users, blind and low vision participants, families with young children, and caregivers. Our envisioned use cases include vacation rental hosts, new caregivers, or people with disabilities themselves documenting issues in their homes or rental spaces and planning renovations. We present key findings from our formative interviews, the design of RASSAR, and results from an initial performance evaluation.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing design and evaluation methods**; **Accessibility systems and tools**.

KEYWORDS

Accessibility, Computer Vision, Virtual/Augmented Reality, Indoor Accessibility Auditing, Object Detection

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1 INTRODUCTION

Safe and accessible living spaces are a fundamental human right [10], and yet, inaccessible housing remains prevalent [12]. In the US, for example, 90% of housing units have accessibility issues such as entrance steps and narrow interior doorways, making them unsafe or inaccessible to people with mobility disabilities [13, 14].

To help improve the safety and accessibility of domestic spaces, researchers and health professionals have created pre-formatted checklists that enable residents and trained professionals to audit and renovate indoor spaces. The popular *Home Safety Self-Assessment Tool* (HSSAT) [6, 17], for example, includes a checklist for nine areas of the home (*e.g.,* kitchens, bathrooms, and bedrooms) with issues such as uneven flooring, cluttered areas, presence of throw rugs, and inaccessible light switches.

With advances in computer vision, augmented reality (AR), and mobile sensors, new approaches for assessing indoor accessibility and safety are now possible. For example, emerging smartphones contain built-in *Light Detection and Ranging* (LiDAR) sensors [1], which can reconstruct indoor spaces with high precision [5]. In this demo paper, we introduce *RASSAR—Room Accessibility and Safety Scanning in Augmented Reality*—a custom mobile AR application for semi-automatically *identifying*, *localizing*, and *visualizing* indoor accessibility and safety issues using LiDAR and real-time computer vision (Figure 1). With RASSAR, the user holds out their phone and slowly scans a space—the tool constructs a real-time parametric model of the 3D scene, attempts to identify and classify known accessibility and safety issues, and visualizes potential problems overlaid in AR.

As initial work, RASSAR currently detects 20 home accessibility and safety issues such as *object dimension* (*e.g.,* table too low), *position* (*e.g.,* cabinet too high), *risky items* (*e.g.,* throw rug), and *lack of assistive device* (*e.g.,* no grab bar near toilet). The tool itself was designed iteratively informed by a design probe study with 18 participants from five key stakeholder groups, including wheelchair users, blind and low vision participants, families with young children, and caregivers. As an early prototype, however, we have not yet conducted user studies with our target participant groups and the scanning process itself is currently inaccessible to blind/low-vision users (*e.g.,* the RASSAR UI requires that the user can see the space they are scanning).

We envision RASSAR as a versatile tool to help build and validate the safety and accessibility of new construction, for residents planning renovations or updating their homes due to a life change (e.g., illness, birth), or for rental agencies like Airbnb to help vet and validate access and safety of rental spaces.

2 THE DESIGN OF RASSAR

To design RASSAR, we conducted a three-stage iterative design process. We first built a rapid technical prototype on an iPhone 13 using *Apple's RoomPlan API* [2]. This prototype allowed us to demonstrate technical feasibility and examine ideal scan conditions [15]. For example, we found that scanning must be conducted at moderate speed (moving at around 0.5 meter per second) while keeping the room tidy and well-lit. Second, using this prototype as a design probe, we conducted a remote formative study with 18 participants across five stakeholder groups. We showed videos of RASSAR, presented new interface mockups and feature ideas, and solicited feedback and co-brainstorming. Finally, based on these formative study findings, we built the current RASSAR system with improved detection performance, user interaction, and interface design.

2.1 Formative Study

To involve key stakeholders into the design process, we conducted a semi-structured formative study with 18 participants drawn from five communities: wheelchair users, families with young children, BLV people, older adults or their caregivers, and occupational therapists. The study included questions regarding people's general accessibility challenges, their reaction towards the RASSAR technical prototype (shown as videos), and a co-design component regarding the interface design of RASSAR. Interviews lasted about one hour and were recorded, transcribed, and analyzed with reflexive thematic coding [4].

We highlight three key findings. First, most participants (16 of 18) were favorable towards RASSAR's prototype because of the measurement and documentation features, the ability to help prepare a home for visitors with accessibility needs, and the ability to customize accessibility issues. Those two participants who were unfavorable or neutral stated "*I don't see the point since I can do these screening by myself*" and "*I don't know*". Second, we observed both similarities and differences in perceived accessibility needs. Thus, RASSAR should be customizable to address different abilities and needs. Finally, participants generally face challenges doing their own indoor accessibility auditing, which they felt could be mitigated by automated indoor auditing methods like RASSAR.

Besides these general findings, we also consulted our participants on technical and design details of the RASSAR prototype. For one, we asked for suggested modifications to our full list of accessibility and safety issues, making sure our rubrics align with the accessibility community. We also redesigned the user interaction and interface based on common preferences among participants in the design probe. Below, we introduce RASSAR's user interface and technical pipeline.

2.2 The RASSAR System

Figure 2 shows an overview of RASSAR's scanning process, which consists of three main steps: rubric customization, room scan, and scan result summary. Importantly, while we aim to support multiple accessibility communities, the scanning process is not yet fully accessible as it requires similar abilities to taking a video recording: holding a phone upright, seeing the scanning space, and interpreting visual results. This is an important area for future work.

2.2.1 Rubric Customization. Because we want to support different type of safety and accessibility needs across user groups, the first step in RASSAR's scanning process is to select one or more target communities: wheelchair user, blind or low vision (BLV), older adults, or children (Figure 2.1). This selection filters RASSAR's 20 accessibility and safety issues to those relevant to the selected community (Figure 3).

RASSAR's audit rubric is drawn from *ADA Design Guidelines* [9], the aforementioned *Home Safety Self Assessment Tool* (HSSAT) [6, 17], the *US Fair Housing Act Design Manual* [7, 14], and others

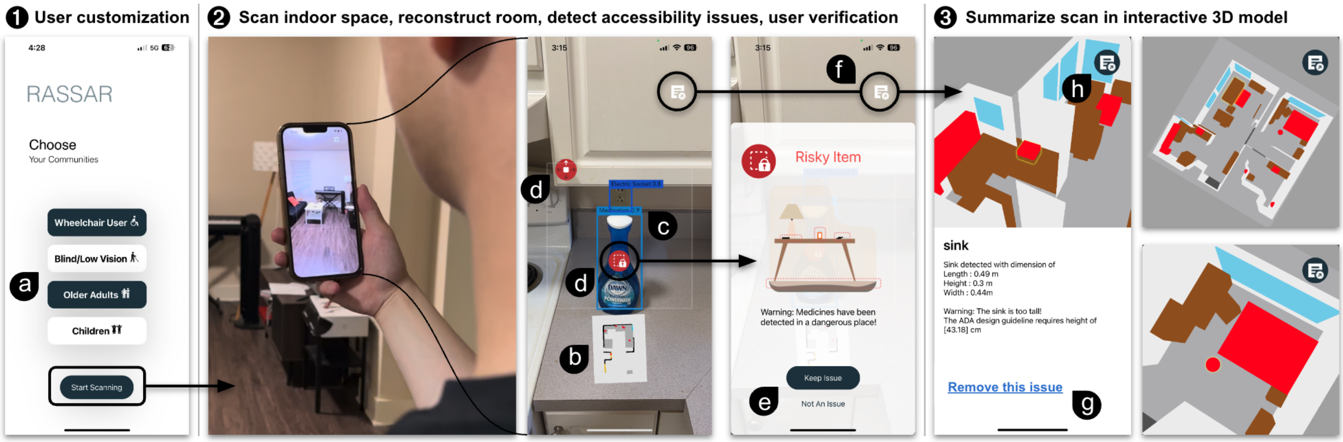

Figure 2: An overview of RASSAR's user interface and scanning process. The user first (1) selects one or more target communities then (2) manually scans the indoor space to reconstruct the room and detect accessibility and safety issues. Real-time results are shown on a top-down minimap (b) and as bounding boxes and pop-up icons in AR (c and d). The user can click on identified features to view more information, see recommended solutions, and to verify validity. Finally, when the scan is complete (3), we show an interactive 3D model of the room reconstruction with detected issues in red, which can be deleted by clicking (g). Scan results can be saved to JSON for further processing by clicking (h).

[11, 16]. The 20 issues fall into four categories (Figure 1.2, Figure 3): *object dimension* (*e.g.,* high table height), *object position* (*e.g.,* out-of-reach light switch), *risky items* (*e.g.,* presence of a sharp object like scissors), and *lack of assistive items* (*e.g.,* missing grab bars). To support extensibility, we encode the rubrics using JSON.

2.2.2 Scan, Reconstruct, Detect and Verify. The second step involves scanning the indoor space with the phone. During the scan, RASSAR continuously reconstructs the room with Apple's RoomPlan API [2], which utilizes LiDAR sensor and camera data to generate a parametric indoor 3D model. We also run a custom trained YOLOV5 [8] model in real time to detect smaller indoor objects related to accessibility and safety such as door knobs and electric sockets, and locate them into 3D space with raycasting [3]. The reconstruction results are shown as a minimap (Figure 2.b) to help the user understand the scanning progress.

The parametric room reconstruction contains size, position and category information, RASSAR analyzes and filters this data in real time with the customized rubrics to detect potential accessibility and safety issues. To notify the user, we show all detected issues in augmented reality with pop-up icons (Figure 2.d, red icons in Figure 3). The user can click these icons to inspect detailed information about the selected issue, and verify if this issue is valid and also relevant to the target person's needs. If not, the user can remove this issue by clicking the appropriate button (Figure 2.e).

2.2.3 Summarize Scan Results. When the scan is finished, the user can click (Figure 2.f) to proceed to the summary phase. Here, we show an interactive room reconstruction in 3D with detected issues highlighted in red. The user can pan, zoom and move the 3D model to inspect scan results, and tap any object to see detailed information (Figure 2.3). The user can also delete detected issues (Figure 2.g) or export all scan results into a JSON file (Figure 2.h).

3 TECHNICAL EVALUATION

To evaluate RASSAR's technical performance, we selected eight home spaces, including seven apartments and one house of varying sizes and layouts. For each space, we conducted a three-step process:

- Step 1: Collect baseline data: manually audit indoor space to identify any existing accessibility and safety issues using RASSAR's accessibility rubrics.
- Step 2: Scan the indoor space with RASSAR to detect accessibility and safety issues.
- Step 3: Compare RASSAR's scan results with baseline.

We repeated Steps 2 and 3 three times to improve experimental robustness resulting in 24 scans across the eight test sites. Overall, our analysis indicates that RASSAR can effectively identify indoor accessibility and safety issues with an average accuracy of 0.71, precision of 0.86, recall of 0.81, and F1 score of 0.83. We observe an average Fleiss' Kappa of 0.76 across scans, indicating substantial consistency. Additionally, RASSAR scanning took 106 secs on average (*SD*=24.8), which is significantly faster than manual auditing which took the lead author approximately 10 mins per room.

4 DISCUSSION AND FUTURE WORK

In this demo paper, we introduced RASSAR, which semi-automatically scans indoor space using LiDAR and real-time computer vision to detect accessibility and safety issues. While the formative study and technical evaluation demonstrate potential, several limitations and opportunities for future work remain.

User Study. Currently, RASSAR scans have only been conducted by the research team. To better assess RASSAR's usability and performance, future work should conduct user studies with participants drawn from our target stakeholder groups. We would also like to examine RASSAR with people who rent their homes using

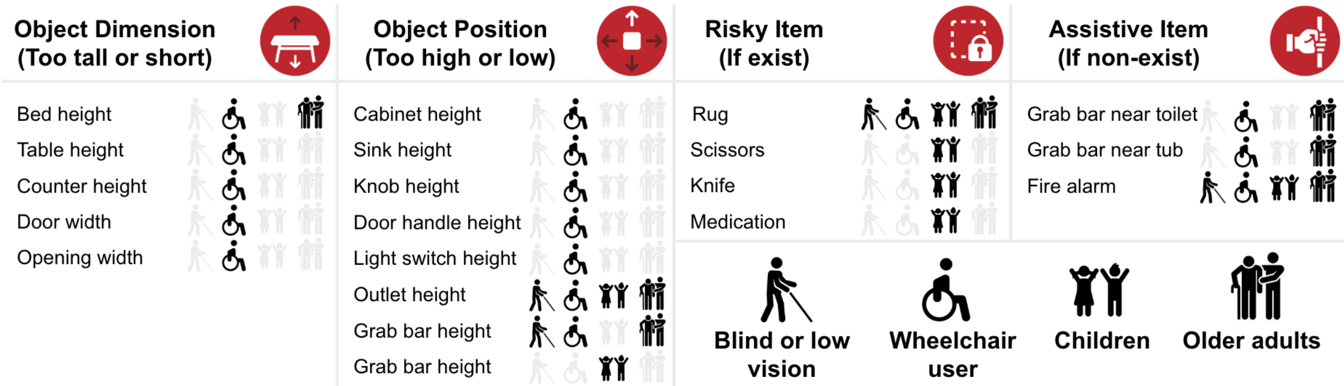

Figure 3: RASSAR can detect 20 types of accessibility and safety issues across four categories: Object Dimension, Object Position, Risky Item, and Assistive Item. Each issue has relevance to certain accessibility communities, marked with black icons.

services like Airbnb or VRBO to better assess how our tool could improve the accessibility and safety of rental spaces.

System Improvements. Currently, RASSAR detects 20 types of accessibility and safety issues (Figure 3)—we would like to expand this list based on literature and our formative study findings (*e.g.*, to support auditing on home entrances and bath facilities). Additionally, we would like to integrate route finding algorithms to detect narrow pathways. We would also like to design an authoring tool to enable target groups to create and encode their own accessibility rubrics (taking advantage of our custom extensible JSON-based rubric definitions). Finally, as noted previously, we would like to improve the accessibility of RASSAR's scanning process to decrease the reliance on upper-body motor dexterity (holding the phone upright for a scan) and the user's visual acuity (to see what is being scanned).

Privacy Protection. RASSAR has been developed with privacy in mind: it runs solely on the user's local mobile devices. However, future expansion of RASSAR may inevitably require cloud computing for more complex indoor understanding tasks, creating potential privacy concerns. Future work should study on data types, sensitivity levels, as well as possible encryption methods involved in indoor accessibility auditing process, in order to better protect indoor data.

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